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Nuclear Experimental Group I

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Research Activities

(I) LIGHT ION NUCLEAR PHYSICS

a. Spectroscopic Study of sd Shell Nuclei through (d,n) Reactions at 25 MeV

(T. Tohei, T. Nakagawa, J. Takamatsu, A. Terakawa, A. Narita, K. Hosomi, H. Orihara, K. Ishii, M. Ohura, G. C. Jon, M. Hosaka, K. Miura, and H. Ohnuma)

A study for proton particle states through (d,n) reactions has been continued on ^{18}O, ^{32}S, and ^{40}Ar by using a 25 MeV deuteron beam from the CYRIC AVF cyclotron and a TOF facility. Observed spectroscopic factors for various states up to about 10 MeV and the proton occupation numbers for the 1d and 2s shells in the ground states were compared with the results from the shell model theory of Wildenthal & Brown.

b. A Study for Neutron Particles States in the ^{41,43,45}Ca Nuclei by Using (d,p) Reactions

(T. Tohei, T. Nakagawa, J. Takamatsu, A. Terakawa, A. Narita, and K. Hosomi)

One neutron transfer study through the (d,p) reactions on ^{40,42,44}Ca has been accomplished by using a 25 MeV deuteron beam from the SF cyclotron at INS and QDD magnetic spectrometer. An isotone dependence for the hole strengths of the 1d and 2s shells in the ground states has been found by summing the spectroscopic factors for the ℓ=0 and 2 transfers.

c. A Study of the Two Protron Transfer Reactions on ^{4}He and ^{16}O

(T. Tohei, T. Nakagawa, J. Takamatsu, A. Terakawa, A. Narita, K. Hosomi, H. Orihara, K. Ishii, M. Ohura, G. C. Jon, M. Hosaka, K. Abe, T. Suehiro, K. Miura, and H. Ohnuma)

Experiments of the (^{3}He,n) reactions on ^{4}He and ^{16}O have been done by using 45 MeV and 30 MeV ^{3}He beams from the CYRIC AVF cyclotron and a TOF facility. Angular distributions of cross sections were compared with results of DWBA calculation with Wildenthal & Brown's wave functions and searched optical potential parameters.

(II) ELECTRON SCATTERING

a. (e,e'n) Experiments on ^{12,13}C and ^{40}Ca *(T. Saito, S. Suzuki, K. Takahisa, C. Takakuwa, T. Tohei, T. Nakagawa, and K. Abe)*

(e,e'n) events for the ^{13}C, ^{40}Ca and ^{12}C nuclei have been measured in the giant resonance energy regions and at E_x=45 MeV, respectively, by using continuous electron beam of 130 MeV from SSTR at Laboratory of Nuclear Science, Tohoku University. Angular correlations between scattered electrons and emitted neutrons were measured with a magnetic spectrometer to detect electrons and more than six NE213 scintillation detectors for neutrons set on or off the reaction plane.

(III) POLARIZATION

a. Quadrupole Mixed-symmetry States in ^{56,58}Fe and ^{54}Cr *(J. Takamatsu, T. Tohei, T. Nakagawa, A. Terakawa, A. Narita, M. Fujiwara, S. Morinobu, I. Katayama, H. Ikegami, K. Katori, S. I. Hayakawa, Y. Fujita, M. Tosaki, and S. Hatori)*

Quadrupole mixed-symmetry 2^+_M states in ^{56,58}Fe and ^{54}Cr have been searched by means of inelastic deuteron and polarized proton scattering experiments at 56 MeV and 65 MeV at the RCNP AVF facility. The measured angular distributions of cross sections and analyzing powers were compared with macroscopic and microscopic DWBA calculation.

b. Stretched 6^- States in the ^{32}S Nucleus *(T. Saito, S. Suzuki, K. Takahisa, C. Takakuwa, T. Tohei, T. Nakagawa, J. Takamatsu, A. Terakawa, K. Hosomi, M. Fujiwara, and Y. Fujita)*

Experiments of the ($\vec{p}$,p'), ($\vec{d}$,d) and (α, α') scatterings on ^{32}S have been continued at 75 MeV, 56 MeV and 120 MeV, respectively, by using beams from the AVF cyclotron at RCNP, Osaka University and the magnetic spectrometer RAIDEN in order to clarify the strengths and fragmentation for the stretched 6^- states.

(IV) NUCLEAR PHYSICS BY CHARGE-EXCHANGE (p,n) REACTION

(H. Orihara, M. Ohura, M. Hosaka, G. C. Jon, K. Ishii, A. Terakawa, A. Narita, K. Hosomi, T. Nakagawa, K. Miura, and H. Ohnuma)

In the course of exploration by the charge-exchange (p,n) reaction for spin-isospin modes of nuclear excitation, and their relation to the π- and ρ-meson exchange interactions, we have studied;

(1) effective N-N interaction in low-energy
(2) test of the (0s0p1s0d) full-space shell model, investigation of Gamow-Teller(GT) strength distribution in sd-shell nuclei
(3) search for the GT-strength distribution in the $f_{7/2}$-shell nuclei
(4) sampling of isovector spin-excitations other than the GT-transition

a. Observation of Isovector $1\hbar\omega$ Spin-flip Excitation by the ^{18}O(p,n)^{18}F Reaction at 35 MeV.

We have performed systematic studies of the (p,n) reactions at E_p=35 MeV for sd-shell nuclei. For sd-shell nuclei, the shell model wave functions by Brown-Wildenthal(BW) are extensively used and the stringent test of the BW wave functions has been achieved. We discuss the observation of isovector $1\hbar\omega$ spin-flip excitation, an illustrating example for which is $0^+ \rightarrow 2^-$ transition, in the ^{18}O(p,n) reaction at E_p=35 MeV. We choose ^{18}O as a target since it provides a good place to test the wave functions for negative parity states. In sd-shell nuclei, spectroscopic amplitudes of unnatural parity transitions leading to the $1\hbar\omega$ jump negative parity states are available only for A=18 nuclei by the BW wave functions.

b. Analog Transition in sd-shell Nuclei Studied by (p,n) Reaction

The isovector team (V_1) in the Lane-potential have been studied based on the experimental data of the (p,n) reaction at E_p=35 MeV in a variety of target nuclei ranging 17<A<39: namely ^{17,18}O, ^{22}Ne, ^{25,26}Mg, ^{27}Al, ^{30}Si, ^{34}S, ^{38}Ar and ^{39}K. From this systematic study, we have deduced mass number (A) dependence of real and imaginary potential depths, and imaginary radius and diffuseness parameters in the isovector term of the Lane-potential.

c. Spin-isospin Excitation in the ^{14}C(p,n)^{14}N Reaction

Differential cross sections for the ^{14}C(p,n)^{14}N reaction were measured at E_p=35 MeV. A number of spin-isospin excitations have been observed including Gamow-Teller type $0^+ \rightarrow 1^+$ and $0\hbar\omega$ and $1\hbar\omega$ jump stretched transitions. Distorted-wave Born-approximation (DWBA) calculations using shell model wave functions have successfully reproduced the experimental results. Renormalization factors introduced to optimize the DWBA fits were 0.5 for the transition leading to the 3.947-MeV 1^+ state, and ~1.0 for those to the ground state, and 2^- and 3^- states, while these factors for the stretched transitions were slightly larger than 1.0. Proton and neutron optical-potential parameters were derived in the course of the present work.

(V) INTERMEDIATE ENERGY PHYSICS

a. A Study on the $\eta\pi^-$ System in the π^-p Reaction at KEK *(T. Tsuru et al., KEK E179 Collaboration)*

We studied the $\eta\pi^-$ system produced in the diffractive reaction $\pi^- p \rightarrow \eta\pi^- p$ at 6 GeV/c to search a meson with non-$q\bar{q}$ quantum number such as $J^{PC}=1^{-+}$ by using charge and gamma spectrometer BENKEI at KEK-PS.

b. (γ,π) Reaction *(T. Yamaya, M. Saito, K. Shoda, H. Yamazaki, T. Taniuchi, and H. Tsubota)*

1) Examination of the Giant Dipole Resonances of ^{11}Be in the (e,π^+) Reaction on ^{11}B

The strength distribution of the giant dipole resonances in ^{11}Be that the mass radius extend beyond the usual nuclear radius have been measured at E_e=200 MeV.

2) Observation of Higher Excited States of ^{9}Li in the (e,π^+) Reaction on ^{9}Be

Spin-dipole resonances of ^{9}Li, which has ΔT=1, ΔS=1, ΔL=1 have been observed in a pion energy region below T^π=50 MeV.

(VI) HEAVY ION PHYSICS

(T. Yamaya, T. Miyamoto, M. Saito, K. Kotajima, K. Gotoh, T. Shinozuka, and M. Fujioka)

a. Production of Focusing Low-Energy Radioactive Beams

Radioactive beam of ^{15}O at E=75 and 65 MeV were obtained in the reaction ^{1}H(^{15}N,^{15}O)n at E=85 MeV. Energy resolution and intensity of beam are 0.6 MeV and 10^4/sec, respectively.

b. Elastic Scattering of Proton Rich Heavy Nucleus

The potential between proton rich and neutron rich nuclei have been studied using the radioactive beam of ^{15}O. Measurements have be made at very small angles in order to study the glory effect.

c. Focussed Mono-Energy Neutron Source by a Heavy Ion Collision

Focussed and mono-energy neutron beam at E_n=4 MeV was produced at 0° in the reaction ^{1}H(HI·X) in coincidence with recocil heavy ions.

(T. Yamaya, M. Saito, M. Fujioka, S. Hatori, T. Itahashi, K. Katori, S. Kato, and S. Ohkubo)

d. Experimental Evidence of Inversion Parity Doublet Band in ^{44}Ti by (^{6}Li,d) Reaction

The $K^\pi=0^+$ and 0^- bands in ^{44}Ti which is one of most considerable interest for the α-cluster structure have been found in the reaction (^{6}Li,d) on ^{40}Ca.

(VII) ION-ATOM COLLISION AND IT'S APPLICATION (PIXE)

a. Inner Shell Ionization *(K. Ishii, H. Orihara, K. Sera and S. Morita)*

Multiple inner shell ionization mechanism for proton and ^{3}He ion bombardments is investigated by measuring characteristic x rays with a high resolution crystal spectrometer. This x-ray spectrometer is also used to the study of chemical effects observed in satellite x-ray spectra.

b. Binding Energy Effect of Inner Shell Electrons in Ion-atom Collisions *(K. Ishii, H. Orihara, I. Katayama, A. Ando, Y. Haruyama, and H. Ogawa)*

Evidence for the increase of K-shell binding energy due to the formation of united atom with projectile and target atom has been investigated by measuring the momentum distribution of scattered particles with the high resolution magnetic spectrometer of RCNP (RAIDEN).

c. Continuum x Rays Emitted from a United Atom *(K. Ishii, K. Maeda, Y. Sera, M. Uda, J. Kawai, and S. Morita)*

Continuum x rays produced by the bombardments of heavy ions (Si, Cr and Cu) for targets of C-Zn are studied by using the RIKEN HILAC. Bremsstrahlung produced by the united atom (United-atomic bremsstrahlung) is experimentally and theoretically investigated.

d. PIXE *(K. Ishii, H. Orihara, N. Suzuki, Y. Iwata, and K. Fujiwara)*

The PIXE system using a crystal spectrometer has been developed for the analysis of chemical states of trace elements.

(VIII) INSTRUMENTS

a. Performance Test of a BaF_2 Detector System for High-energy γ-ray *(H. Orihara, M. Ohura, M. Hosaka, G. C. Jon, K. Ishii, A. Terakawa, A. Narita, K. Hosomi, T. Nakagawa, K. Miura, and H. Ohnuma)*

We have constructed a high-energy γ-ray measurement system composed of twelve pieces of BaF_2 and plastic scintillators. The detector assembly is placed in 90° direction with respect to the incident beam and 15 cm from the target. A lead collimator is placed between the detector and the semicircular target-chamber, in order to obtain a good detector response by collimating high-energy γ rays onto the central BaF_2 scintillator. Unexpected γ-rays are rejected by the time-of-flight (TOF) analysis, and major events due to neutrons are rejrected by TOF, together with the pulse-shape analysis. Performance test for this system has been carried out successfully by counting monoenergetic γ-rays at E_γ=12.7, 15.1, 27, and 30 MeV from ^{12}C+p reaction.

b. Large Solid Angle Magnetic Spectrograph for Photopion Production *(T. Yamaya, K. Shoda, M. Saito, H. Yamazaki, and T. Taniuchi)*

Charged pions from (γ,π) reaction were measured with a new large solid angle spectrograph for a dependence of photopion production on mass of nucleus.

c. Vertical Drift Counter for Magnetic Spectrograph *(T. Yamaya, T. Hotta, T. Satoh, K. Shoda, M. Saito, H. Yamazaki, and T. Taniuchi)*

Vertical Drift Counter for the large-solid angle magnetic spectrograph have been developed. The time resolution of drift time is less than 20 n second.

d. Soft Ware Development of Positron-CT *(K. Ishii, H. Orihara, S. Watanuki, and K. Yamada)*

Error estimation on positron images has been studied for a quantitative examination of the function of brain.

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Doctor Thesis (March 1991)

D1) **A Study of Mixed-symmetry 2^+ States in the ^{54}Cr and ^{56,58}Fe Nuclei by Proton and Deuteron Inelastic Scatterings**, *Jun Takamatsu*

Master Theses (March 1991)

M1) **A High Energy γ-ray Measurement System Composed by BaF_2 Scintillators**, *Masahito Hosaka*
M2) **A Test of Radioactive Beam Using Inversion Kinematics Method**, *Tsuyoshi Miyamoto*
M3) **Spectroscopic Study of the ^{41,43,45}Ca Nuclei through (d,p) Reactions**, *Akiko Narita*